

*36 p.*

# UNPUBLISHED PRELIMINARY DATA

N64-16321

CODE-1

(NASA CR-55543) OTS

*inside*  
SUMMARY REPORT OF R-71 PROGRAM

OTS PRICE

XEROX \$ 3.60 per  
MICROFILM \$ 1.28 per

Prepared by

L. E. Crogan

23 December 1963

*o reger*

1683002

U. S. NAVAL ORDNANCE LABORATORY  
White Oak, Silver Spring, Maryland

(NASA Order R-71)

## SUMMARY REPORT ON R-71 PROGRAM

A drag and stability program involving two configurations (figure 1) was conducted in the NOL Pressurized Ballistics Range No. 3 at velocities of approximately 16,000 fps and at an ambient pressure of 90 mm Hg. The tests were conducted in air, nitrogen, and several combinations of nitrogen and carbon dioxide. These combinations were as follows:

- (a) 15%N<sub>2</sub> - 85%CO<sub>2</sub>
- (b) 85%N<sub>2</sub> - 15%CO<sub>2</sub>
- (c) 95%N<sub>2</sub> - 5%CO<sub>2</sub>
- (d) 80%N<sub>2</sub> - 20%CO<sub>2</sub>

The velocities were obtained with 0.500 inch maximum diameter models launched from a 20 mm two-stage light-gas gun. The composition of the atmosphere in the range was determined both by gas chromatograph measurements made at NOL and by mass spectrometer measurements conducted by the Bureau of Standards. Gas samples were extracted from three points along the range and in most cases agreement between the two methods was within 1% by volume of the individual gas constituents. Greater disagreements in the two methods of analysis were attributed to leakage of the bottled sample sent to the Bureau of Standards.

Speed of sound values were obtained both by experiment and by calculation. The calculated values were determined at three points along the length of the range using gas composition values obtained with the gas chromatograph and with measured values of the temperature. The experimental values for speed of sound were obtained at each end of the instrumented portion of the range. Each of the two units incorporated for this purpose consisted of a sound generator and a pickup. The distance between the generator and pickup was known and the time for the sound to travel this distance was obtained from oscilloscope traces. From these measurements, the speed of sound was determined.

In the majority of cases, the calculated and experimental values of speed of sound differed by less than 1%.

There are twenty-seven spark shadowgraph stations in the Pressurized Ballistics Range spaced alternately 5 and 8 feet apart. Analysis samples were taken from stations 2, 15, and 26. The experimental speed of sound instrumentation was located between stations 2 and 4 and stations 25 and 27. Figure 2

is a schematic of the system showing the location of the various instrumentation.

Nitrogen was injected directly into the range from storage bottles near the launcher end of the range for shots requiring 100% N<sub>2</sub> atmosphere. Shots requiring mixtures of N<sub>2</sub> and CO<sub>2</sub> utilized a mixing tank. The gases were injected into this tank in the desired proportions. After mixing, the gas was then admitted into the range proper.

The range was evacuated as low as possible (to approximately 3 mm Hg. pressure) before the gases were injected. The gases were then admitted until the desired range pressure was obtained (about 90 mm Hg). Oxygen contamination using this technique resulted in approximately 1% by volume.

Several interesting phenomena were observed during the course of this program. Turbulent disturbances were observed both on the model and in the wake of both configurations during tests in atmospheres high in CO<sub>2</sub> content. It was also noted that the magnitude of the visible radiation greatly increased for atmospheres of 10% CO<sub>2</sub> and less.

In Tables I through X, a complete summary of the final data is presented. The aerodynamic coefficients and derivatives are also present in graphical form as a function of both Mach number and mean squared yaw. Included also are listings of the Naval Ordnance Laboratory's gas chromatography analyses and the Bureau of Standards' mass spectrometric analyses.

## LIST OF SYMBOLS

$a$	=	calculated speed of sound in ambient atmosphere
$C_D = \frac{D_t}{qS}$	=	total drag coefficient based on the maximum body cross-sectional area ( $S$ ) of the model
$C_{M\alpha}$	=	(slope of the pitching moment)/ $qSd$ = slope of the pitching moment coefficient referred to the CG of the model
$C_{Mq} + C_{M\dot{\alpha}}$	=	(slope of yaw damping moment due to $q$ )/ $\frac{d}{2V} qSd$ + (slope of yaw damping moment due to $\dot{\alpha}$ )/ $\frac{d}{2V} qSd$ = slope of damping moment coefficient referred to the CG of the model
$C_{N\alpha}$	=	(slope of normal force)/ $qS$ = slope of normal force coefficient
CG	=	center of gravity
CP	=	center of pressure
$d$	=	maximum diameter of model
$D_t$	=	component of the aerodynamic force directed along the trajectory
Exp. $a_{down}$	=	speed of sound measured experimentally downrange
Exp. $a_{up}$	=	speed of sound measured experimentally uprange
$l$	=	length of model
$M$	=	Mach number (usually based on midrange value of $V$ )
$p$	=	range ambient pressure
P.E.	=	probable error based on accuracy of data fitting (P.E. swerve, swerve equation; P.E. yaw, yaw equation)
$q = \frac{\rho V^2}{2}$	=	dynamic pressure; or $q$ = lateral component of angular velocity of model
$R_e d = \frac{\rho V d}{\mu}$	=	Reynolds number based on maximum diameter ( $d$ ) of model

$S = \frac{\pi d^2}{4}$	=	maximum cross-sectional area of model
$V$	=	velocity (usually a midrange value)
$\alpha$	=	angle of attack
$\dot{\alpha}$	=	rate of change of angle of attack with time
$\overline{\delta^2}$	=	mean squared yaw
$\mu$	=	coefficient of viscosity
$\rho$	=	density of air

#### SUBSCRIPTS

CG	coefficient corrected to CG location of 0.337 calibers for the A-1 configuration and 0.474 calibers for the V-1 configuration measured from the base of the model.
o	coefficient corrected to zero yaw
B	quantity measured in calibers from base of model (one caliber = one maximum diameter of model)

TABLE I  
GAS CHROMATOGRAPHY ANALYSES

<u>Round</u>	<u>Location</u>	<u>%N<sub>2</sub></u>	<u>%O<sub>2</sub></u>	<u>%CO<sub>2</sub></u>
4848	downrange	94.7	3.3	2.0
	midrange	96.7	2.9	0.4
	uprange	97.0	3.0	
4849	downrange	95.1	4.2	0.7
	midrange	96.8	2.6	0.6
	uprange	98.2	1.6	0.2
4850	downrange	95.5	3.4	1.1
	midrange	96.6	2.5	0.9
	uprange	97.9	1.8	0.3
4851	downrange	99.5	0.5	
	midrange	96.1	3.1	0.8
	uprange	99.2	0.8	
4852	downrange	13.4	1.2	85.4
	midrange	33.2	8.5	58.3
	uprange	21.4	4.2	74.4
4854	downrange	98.3	1.4	0.3
	midrange	96.6	2.5	0.9
	uprange	98.1	1.4	0.5
4856	downrange	98.7	1.0	0.3
	midrange	97.7	1.6	0.7
	uprange	98.2	1.1	0.7
4857	downrange	98.8	0.9	0.3
	midrange	97.6	1.6	0.8
	uprange	98.2	1.4	0.4
4858	downrange	14.8	2.0	83.2
	midrange	24.8	5.2	70.0
	uprange	22.1	4.4	73.5
4864	downrange	98.6	1.1	0.3
	midrange	96.7	2.6	0.7
	uprange	97.5	1.9	0.6
4865	downrange	98.3	1.1	0.6
	midrange	97.5	1.5	1.0
	uprange	96.9	2.2	0.9

GAS CHROMATOGRAPHY ANALYSES (cont.)

<u>Round</u>	<u>Location</u>	<u>%N<sub>2</sub></u>	<u>%O<sub>2</sub></u>	<u>%CO<sub>2</sub></u>
4866	downrange	16.6	2.2	81.2
	midrange	24.8	5.1	70.1
	uprange	21.5	3.9	74.6
4870	downrange	16.8	1.4	81.8
	midrange	22.9	4.1	73.0
	uprange	14.9	1.4	83.7
4871	downrange	99.2	0.5	0.3
	midrange	99.6	0.3	0.1
	uprange	99.6	0.4	
4872	downrange	16.9	1.6	81.5
	midrange	16.5	1.6	81.9
	uprange	17.4	2.0	80.6
4873	downrange	18.5	1.6	79.9
	midrange	19.2	1.7	79.1
	uprange	19.3	1.9	78.8
4874	downrange	14.4	1.3	84.3
	midrange	14.0	1.3	84.7
	uprange	15.4	1.6	83.0
4875	downrange	14.9	1.4	83.7
	midrange	14.9	1.5	83.6
	uprange	15.9	1.8	82.3
4876	downrange	20.6	2.7	76.7
	midrange	20.5	2.6	76.9
	uprange	20.9	2.7	76.4
4877	downrange	99.3	0.4	0.3
	midrange	99.7	0.3	
	uprange	99.6	0.4	
4878	downrange	13.8	0.9	85.3
	midrange	13.6	1.1	85.3
	uprange	14.3	1.2	84.5
4879		air		
4882		air		

GAS CHROMATOGRAPHY ANALYSES (cont.)

<u>Round</u>	<u>Location</u>	<u>%N<sub>2</sub></u>	<u>%O<sub>2</sub></u>	<u>%CO<sub>2</sub></u>
4884	downrange	96.0	0.5	3.5
	midrange	95.4	0.7	3.9
	uprange	95.2	0.7	4.1
4887	downrange	93.4	0.6	6.0
	midrange	92.9	0.7	6.4
	uprange	92.8	0.8	6.4
4888		air		
4889	downrange	16.8	1.2	82.0
	midrange	17.7	1.5	80.8
	uprange	18.5	1.8	79.7
4891		air		
4894	downrange	15.1	1.6	83.3
	midrange	15.3	1.7	83.0
	uprange	16.5	1.9	81.6
4895	downrange	99.7	0.3	
	midrange	99.7	0.3	
	uprange	99.7	0.3	
4896	downrange	99.5	0.5	
	midrange	99.6	0.4	
	uprange	99.6	0.4	
4902	downrange	99.4	0.6	
	midrange	99.6	0.4	
	uprange	99.6	0.4	
4903		air		
4904	downrange	78.4	0.6	21.0
	midrange	79.0	0.9	20.1
	uprange	78.3	1.0	20.7
4905	downrange	85.1	1.1	13.8
	midrange	84.1	1.1	14.8
	uprange	84.4	1.5	14.1
4906	downrange	85.6	0.2	14.2
	midrange	85.8	0.3	13.9
	uprange	85.4	0.4	14.2

GAS CHROMATOGRAPHY ANALYSES (cont.)

<u>Round</u>	<u>Location</u>	<u>%N<sub>2</sub></u>	<u>%O<sub>2</sub></u>	<u>%CO<sub>2</sub></u>
4908	downrange	84.7	0.5	14.8
	midrange	84.9	0.7	14.4
	uprange	84.2	0.6	15.2
4909	downrange	86.7	0.8	12.5
	midrange	85.4	0.6	14.0
	uprange	85.4	0.7	13.9
4911	downrange	85.9	0.2	13.9
	midrange	85.1	0.5	14.4
	uprange	85.4	0.6	14.0

TABLE II  
MASS SPECTROMETRIC ANALYSES

<u>Round</u>	<u>%Dry Air*</u>	<u>%N<sub>2</sub></u>	<u>%CO<sub>2</sub></u>	<u>%H<sub>2</sub>O</u>
4848	30.0	68.4	1.2	0.4
4849	14.7	84.8	---	0.4
4850	14.5	85.1	---	0.4
4851	18.3	81.4	---	0.3
4852	38.0	8.7	52.9	0.4
4853	48.8	7.2	43.7	0.3
4854	12.4	87.4	---	0.2
4855	10.8	89.0	---	0.3
4856	7.0	92.7	---	0.3
4857	7.1	92.7	---	0.2
4858	29.8	8.8	61.2	0.2
4864	11.0	88.8	---	0.2
4865	85.3	14.6	---	0.1
4866	24.1	9.9	65.6	0.3
4870	7.0	11.6	81.2	0.2
4871	1.9	98.0	---	0.1
4872	88.0	1.7	9.9	0.4
4873	7.6	14.6	77.6	0.2
4874	9.6	9.1	81.1	0.2
4875	7.3	11.0	81.6	0.1
4876	13.1	13.2	73.4	0.2
4877	1.3	98.5	---	0.2
4878	32.9	10.8	55.6	0.7
4884	2.3	93.1	4.4	0.1
4887	2.7	90.6	6.7	---
4889	6.9	14.4	78.8	---
4890	4.0	90.0	6.0	---
4894	8.2	11.4	80.3	0.1
4895	1.0	98.8	---	0.2
4896	1.5	98.5	---	---
4902	13.5	86.3	---	0.1
4904	3.6	76.1	20.2	---
4905	4.2	81.1	14.7	---
4906	1.7	84.0	14.2	---
4907	1.2	85.2	13.5	---
4908	3.1	83.1	13.8	---
4909	2.6	83.6	13.8	---
4911	55.6	38.2	6.0	0.2

\*Nitrogen      78.03 mole percent  
 Oxygen        20.99 mole percent  
 Argon         0.94 mole percent  
 Carbon Dioxide 0.03 mole percent

TABLE III

DRAG AND STABILITY DATA OBTAINED FOR V-1 CONFIGURATION IN A  
100% NITROGEN ATMOSPHERE

<u>Round</u>	<u>4848</u>	<u>4877</u>	<u>4871</u>	<u>4895</u>	<u>4896</u>
M	12.38	13.76	13.41	12.70	13.60
P (in. Hg)	3.39	3.56	3.53	3.54	3.52
$\frac{\delta^2}{\delta^2}$ (deg. <sup>2</sup> )	58	81	11	137	52
$Re_d \times 10^{-6}$	0.410	0.477	0.462	0.438	0.466
$C_D$	0.370	0.3809	0.3522	0.4101	0.3521
$\pm P.E.$	0.001	0.0005	0.0006	0.0006	0.0007
$C_{D_0}$	0.336	0.3339	0.3458	0.3306	0.3219
P.E. yaw (deg.)	1.1	0.6		1.1	0.6
P.E. swerve (in.)	0.02	0.02		0.04	0.02
$C_{M_x}/\text{deg.}$	-0.00188	-0.00216	-0.0026	-0.00215	-0.00182
$\pm P.E.$	0.00004	0.00002	0.0001	0.00003	0.00002
$C_{M_{xCG}}/\text{deg.}$	-0.00191	-0.00214		-0.00313	-0.00202
$C_{M_{xCG_0}}/\text{deg.}$	-0.00181	-0.00201		-0.00290	-0.00193
$C_{N_x}/\text{deg.}$	-0.021	-0.021		-0.023	-0.021
$\pm P.E.$	0.001	0.001		0.002	0.001
$C_{N_{x_0}}/\text{deg.}$	-0.020	-0.019		-0.020	-0.020
$C_{M_q} + C_{M_{\dot{x}}}$	-0.7	-0.6		-0.6	0
$\pm P.E.$	1.2	0.5		0.8	0.7
(CP-CG) Cal.	0.091	0.104		0.130	0.088
CG <sub>B</sub> (in.)	0.237	0.238	0.240	0.234	0.233
l (in.)	0.576	0.575	0.575	0.575	0.575
d (in.)	0.500	0.500	0.500	0.500	0.500
a (ft/sec)	1146	1151	1150	1151	1151
Exp. a <sub>up</sub> (ft/sec)	1154	1148	1149	1149	1146
Exp. a <sub>down</sub> (ft/sec)		1149	1151	1150	1150
Stations Used	8-27	3-37	5-27	3-27	3-27
Location of Sample Used for Reduction	midrange	midrange & Bu. Std.	midrange & Bu. Std.	midrange & Bu. Std.	midrange & Bu. Std.

TABLE IV

DRAG AND STABILITY DATA OBTAINED FOR V-1 CONFIGURATION IN AIR AND IN A 15% CARBON DIOXIDE - 85% NITROGEN ATMOSPHERE

<u>Round</u>	<u>4908</u>	<u>4840</u>
M	14.67	14.22
P (in. Hg)	3.52	3.91
$\frac{1}{2} \delta^2$ (deg. <sup>2</sup> )	190	19
$Re_d \times 10^{-6}$	0.534	0.533
$C_D$	0.441	0.3409
$\pm P.E.$	0.001	0.0008
$C_{D_0}$	0.331	0.3299
P.E. yaw (deg.)	1.0	
P.E. swerve (in.)	0.02	
$C_{M_x}/\text{deg.}$	-0.00242	-0.0019
$\pm P.E.$	0.00002	
$C_{M_{x_{CG}}}/\text{deg.}$	-0.00255	
$C_{L_{a_{CG_0}}}/\text{deg.}$	-0.00223	
$C_{N_x}/\text{deg.}$	-0.023	
$\pm P.E.$	0.001	
$C_{M_q} + C_{M_{\dot{x}}}$	-0.3	
$\pm P.E.$	0.5	
(CP-CG) Cal.	0.103	
CG <sub>B</sub> (in.)	0.233	0.240
l (in.)	0.575	0.575
d (in.)	0.500	0.500
a (ft/sec)	1099	1134
Exp. a <sub>up</sub> (ft/sec)	1091	
Exp. a <sub>down</sub> (ft/sec)	1100	
Stations Used	6-27	5-27
Location of Sample Used for Reduction	midrange and Bu. Std.	air

TABLE V  
DRAG AND STABILITY DATA OBTAINED FOR V-1 CONFIGURATION IN A  
15% NITROGEN - 85% CARBON DIOXIDE ATMOSPHERE

<u>Round</u>	<u>4875</u>	<u>4872</u>	<u>4873</u>	<u>4873</u>	<u>4874</u>	<u>4874</u>
M	17.59	16.30	16.27	16.21	16.56	16.41
P (in. Hg)	3.54	3.53	3.51	3.51	3.57	3.57
$\frac{1}{\delta^2}$ (deg. <sup>2</sup> )	12	126	95	95	12	12
$Re_d \times 10^{-6}$	0.828	0.665	0.749	0.743	0.786	0.771
$C_D$	0.349	0.4146	0.3889	0.3909	0.3254	0.3298
$\pm P.E.$	0.003	0.0004	0.0002	0.0002	0.0004	0.0004
$C_{D_0}$	0.342	0.3415	0.3338	0.3358	0.3184	0.3228
P.E. yaw (deg.)		0.9	1.2	1.2	0.7	0.7
P.E. swerve (in.)		0.02	0.01	0.01	0.02	0.02
$C_{M_x}/\text{deg.}$	-0.0034	-0.00265	-0.00261	-0.00264	-0.00312	-0.00316
$\pm P.E.$		0.00002	0.00004	0.00004	0.00006	0.00006
$C_{M_x/CG}/\text{deg.}$		-0.00261	-0.00267		-0.00305	
$C_{M_x/CG_0}/\text{deg.}$		-0.00240	-0.00251		-0.00303	
$C_{N_x}/\text{deg.}$		-0.0261	-0.025	-0.025	-0.025	-0.025
$\pm P.E.$		0.0009	0.002	0.002	0.006	0.006
$C_{N_x/CG_0}/\text{deg.}$		-0.0251	-0.024	-0.024	-0.025	-0.025
$C_{M_q} + C_{M_x}$	+0.2	-1.5	-1.5	-2.1	-2.1	-2.1
$\pm P.E.$		0.4	0.8	0.8	1.1	1.1
(CP-CG) Cal.		0.102	0.104	0.104	0.126	0.11
CG <sub>B</sub> (in.)	0.238	0.238	0.236	0.236	0.239	0.23
l (in.)	0.576	0.574	0.575	0.575	0.575	0.575
d (in.)	0.501	0.500	0.501	0.501	0.500	0.500
a (ft/sec)	914.0	918.1	924.2	927.6	912.1	920.0
Exp. a <sub>up</sub> (ft/sec)	916.4	920.4	925.1	925.1	917.8	917.8
Exp. a <sub>down</sub> (ft/sec)	915.5	920.9	924.1	924.1	917.3	917.3
Stations Used	17-27	3-24	2-27	2-27	2-27	2-27
Location of Sample Used for Reduction	midrange & Bu. Std.	midrange	midrange	Bu. Std.	midrange	Bu. Std.

TABLE VI  
DRAG AND STABILITY DATA OBTAINED FOR A-1 CONFIGURATION IN A 100% NITROGEN ATMOSPHERE

<u>Round</u>	<u>4849</u>	<u>4849</u>	<u>4850</u>	<u>4850</u>	<u>4864</u>	<u>4864</u>	<u>4865</u>	<u>4902</u>	<u>4851</u>	<u>4854</u>	<u>4856</u>	<u>4857</u>
M	12.34	12.30	12.27	12.24	13.40	13.38	13.13	13.88	12.28	12.16	13.84	13.10
P (in. Hg)	3.58	3.58	3.87	3.87	3.62	3.62	3.61	3.50	3.80	3.58	3.54	3.53
$\frac{\partial^2}{\partial^2}$ (deg. <sup>2</sup> )	12	12	264	264	367	367	233	38	74	7	32	74
$Re_d \times 10^{-6}$	0.430	0.427	0.460	0.457	0.471	0.470	0.464	0.471	0.451	0.44	0.477	0.451
$C_D$	0.7080	0.7127	0.730	0.735	0.7652	0.7663	0.7468	0.722	0.710	0.712	0.720	0.707
$\pm P.E.$	0.0009	0.0009	0.002	0.002	0.0005	0.0005	0.0002	0.001	0.002	0.002	0.002	0.002
$C_{D_0}$	0.7068	0.7115	0.704	0.709			0.7240	0.718	0.703	0.711	0.717	0.700
P.E. yaw (deg.)			1.1	1.1	1.4	1.4	1.4					
P.E. swerve (in.)			0.02	0.02	0.01	0.01	0.01					
$C_{M_1}/\text{deg.}$	-0.0007	-0.0007	-0.00089	-0.00090	-0.00130	-0.00130	-0.00096	-0.0007	-0.0009	-0.0007	-0.0008	
$\pm P.E.$	0.0002	0.0002	0.00001	0.00001	0.00002	0.00002	0.00001		0.0003			
$C_{M_1 CG}/\text{deg.}$	-0.0007	-0.0007	-0.00096	-0.00068	-0.00132		-0.00085	-0.0007	-0.0008	-0.0007	-0.0008	
$C_{M_1 CG_0}/\text{deg.}$			-0.00038		-0.00051		-0.00034					
$C_{N_1}/\text{deg.}$			-0.0171	-0.0172	-0.0176	-0.0176	-0.0180					
$\pm P.E.$			0.0005	0.0005	0.0003	0.0003	0.0005					
$C_{H_1}/\text{deg.}$			-0.0152	-0.0153			-0.0163					
$C_{M_q} + C_{M_1}$			-0.3	-0.3	-0.4	-0.4	-0.1					
$\pm P.E.$			0.5	0.5	0.7	0.7	0.8					
(CP-CG) Cal.			0.052	0.052	0.079	0.079	0.053					
CG <sub>3</sub> (in.)	0.170	0.170	0.166	0.166	0.170	0.170	0.171	0.165	0.165	0.166	0.172	0.166
l (in.)	0.410	0.410	0.410	0.410	0.409	0.409	0.411	0.410	0.410	0.410	0.408	0.409
d (in.)	0.499	0.499	0.498	0.498	0.498	0.498	0.499	0.498	0.498	0.500	0.499	0.500
a (ft/sec)	1146	1149	1146	1149	1147	1149	1142	1151	1146	1146	1148	1148
Exp. $a_{up}$ (ft/sec)	1150	1150	1153	1153	1147	1147	1151	1151	1159	1149	1146	1145
Exp. $a_{down}$ (ft/sec)	1149	1149	1155	1155	1151	1151	1149	1152	1156	1146	1148	1148
Stations Used	5-27	5-27	5-26	5-26	2-27	2-27	8-27	6-27	16-27	11-27	14-27	8-24
Location of Sample Used for Reduction	midrange	Bu. Std.	midrange	Bu. Std.	uprange	Bu. Std.	midrange	midrange	midrange	midrange	midrange	midrange
								& Bu. Std.	& Bu. Std.	& Bu. Std.	& Bu. Std.	

TABLE VII

DRAG AND STABILITY DATA OBTAINED FOR A-1 CONFIGURATION IN A  
5% CARBON DIOXIDE - 95% NITROGEN ATMOSPHERE

<u>Round</u>	<u>4884</u>	<u>4887</u>
M	13.60	13.48
P (in. Hg)	3.54	3.53
$\bar{s}^2$ (deg. <sup>2</sup> )	234	45
$Re_d \times 10^{-6}$	0.474	0.473
$C_D$	0.7387	0.7142
$\pm P.E.$	0.0007	0.0007
$C_{D_0}$	0.7158	0.7098
P.E. yaw (deg.)	2.4	0.4
P.E. swerve (in.)	0.03	0.02
$C_{M_x}/\text{deg.}$	-0.00074	-0.000348
$\pm P.E.$	0.00007	0.000007
$C_{M_x}_{CG}/\text{deg.}$	-0.00093	-0.000480
$C_{M_x}_{CG_0}/\text{deg.}$	-0.00042	-0.000381
$C_{N_x}/\text{deg.}$	-0.0183	-0.016
$\pm P.E.$	0.0008	0.002
$C_{N_x}_0/\text{deg.}$	-0.0166	-0.016
$C_{M_q} + C_{M_x}$		-2.6
$\pm P.E.$		0.4
(CP-CG) Cal.	0.041	0.021
CG <sub>B</sub> (in.)	0.163	0.163
l (in.)	0.410	0.407
d (in.)	0.498	0.497
a (ft/sec)	1136	1126
Exp. a <sub>up</sub> (ft/sec)	1129	1124
Exp. a <sub>down</sub> (ft/sec)	1132	1124
Stations Used	2-27	2-27
Location of Sample Used for Reduction	midrange & Bu. Std.	midrange & Bu. Std.

TABLE VIII

DRAG AND STABILITY DATA OBTAINED FOR A-1 CONFIGURATION IN A  
15% CARBON DIOXIDE - 85% NITROGEN ATMOSPHERE AND IN A  
20% CARBON DIOXIDE - 80% NITROGEN ATMOSPHERE

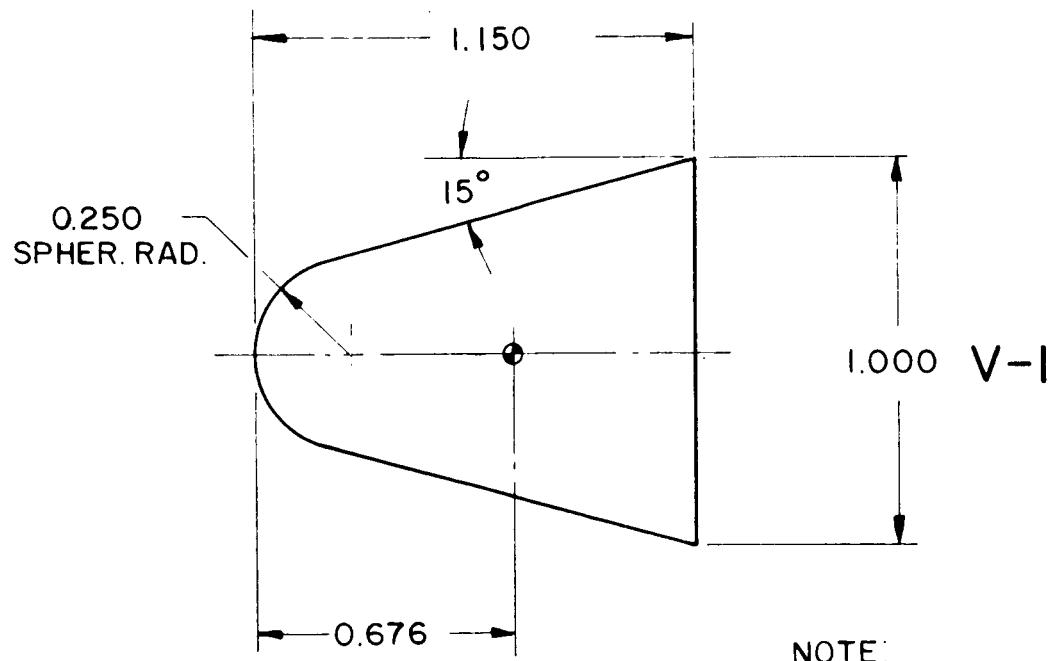
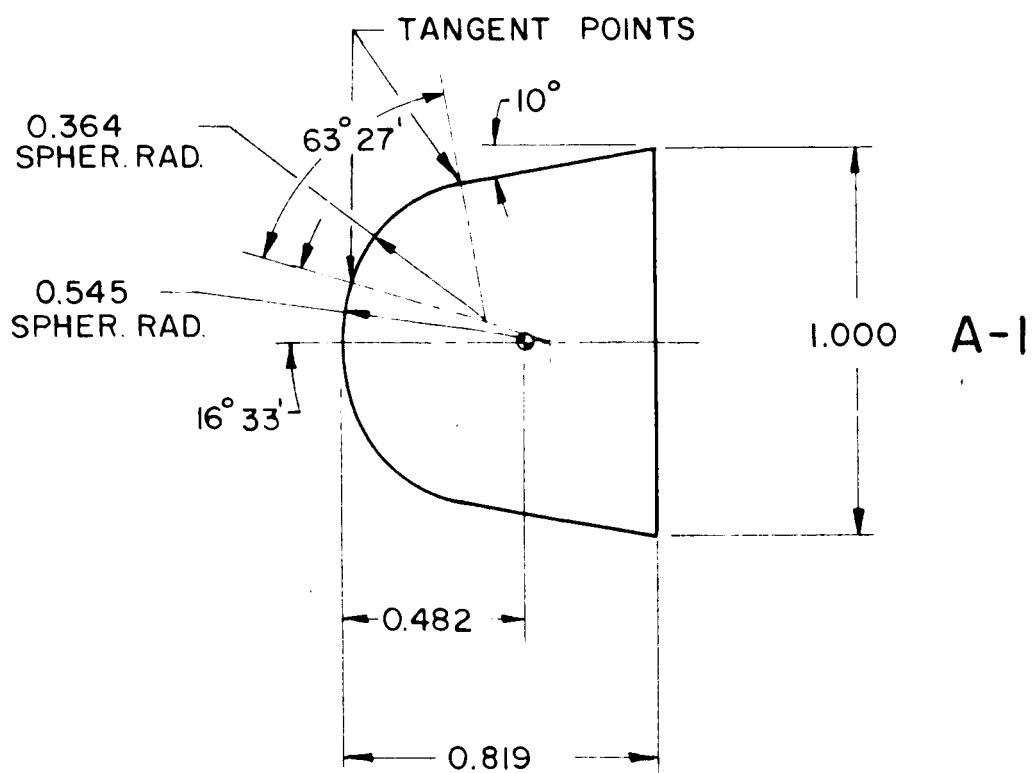
<u>Round</u>	<u>4906</u>	<u>4909</u>	<u>4911</u>	<u>4905</u>	<u>4904</u>
M	14.40	14.18	14.49	14.29	14.46
P (in. Hg)	3.54	3.56	3.54	3.50	3.50
$\frac{\partial^2}{\delta^2}$ (deg. <sup>2</sup> )	22	44	87	30	16
$Re_d \times 10^{-6}$	0.519	0.518	0.526	0.516	0.532
$C_D$	0.7271	0.6988	0.7196	0.7244	0.736
$\pm P.E.$	0.0008	0.0005	0.0005	0.0006	0.001
$C_{D_0}$	0.7249	0.6945	0.7111	0.7215	0.734
P.E. yaw (deg.)			1.4	1.2	0.6
P.E. swerve (in.)			0.02	0.01	0.02
$C_{M_q}/\text{deg.}$	-0.00030	-0.00027	-0.00051	-0.00052	-0.00032
$\pm P.E.$			0.00002	0.00003	0.00002
$C_{M_{q_{CG}}}/\text{deg.}$	-0.00026	-0.00019	-0.00056	-0.00076	-0.00048
$C_{M_{q_{CG_0}}}/\text{deg.}$			-0.00037	-0.00069	-0.00044
$C_{N_x}/\text{deg.}$			-0.0175	-0.0173	-0.0167
$\pm P.E.$			0.0004	0.0007	0.0009
$C_{N_{x_0}}/\text{deg.}$			-0.0169	-0.0171	-0.0166
$C_{M_q} + C_{M_x}$			-1.7		-1
$\pm P.E.$			0.7		1
(CP-CG) Cal.			0.027	0.030	0.019
CG <sub>B</sub> (in.)	0.162	0.159	0.165	0.161	0.163
l (in.)	0.409	0.407	0.410	0.409	0.409
d (in.)	0.495	0.498	0.497	0.498	0.498
a (ft/sec)	1101	1101	1100	1097	1080
Exp. a <sub>up</sub> (ft/sec)	1095	1094	1098	1095	1075
Exp. a <sub>down</sub> (ft/sec)	1096	1095	1099	1097	1078
Stations Used	6-27	2-27	3-27	3-27	3-27
Location of Sample Used for Reduction	midrange & Bu. Std.	midrange & Bu. Std.	midrange	midrange & Bu. Std.	midrange & Bu. Std.

TABLE IX  
DRAG AND STABILITY DATA OBTAINED FOR A-1 CONFIGURATION IN A  
85% CARBON DIOXIDE - 15% NITROGEN ATMOSPHERE

<u>Round</u>	<u>4889</u>	<u>4894</u>	<u>4878</u>	<u>4876</u>	<u>4876</u>
M	16.16	17.44	17.21	16.68	16.54
P (in. Hg)	3.57	3.53	3.51	3.52	3.52
$\frac{\delta_2}{\delta}$ (deg. <sup>2</sup> )	63	41	114	98.5	98.5
$Re_d \times 10^{-6}$	0.758	0.813	0.802	0.755	0.741
$C_D$	0.7142	0.6960	0.7154	0.7068	0.7171
$\pm P.E.$	0.0004	0.0006	0.0004	0.0003	0.0003
$C_{D_0}$	0.7080	0.6920	0.7042	0.6971	0.7074
P.E. yaw (deg.)		1.0	0.9	0.8	0.8
P.E. swerve (in.)		0.02	0.02	0.02	0.02
$C_{M_1}/\text{deg.}$	-0.00029	-0.00021	-0.000444	-0.000329	-0.000333
$\pm P.E.$		0.00001	0.000007	0.000005	0.000005
$C_{M_1 CG}/\text{deg.}$	-0.00011	-0.00029	-0.000603	-0.000554	-0.000057
$C_{M_1 CG_0}/\text{deg.}$		-0.00020	-0.000352	-0.000337	
$C_{N_3}/\text{deg.}$		-0.0145	-0.0163	-0.0168	-0.0170
$\pm P.E.$		0.0003	0.0002	0.0003	0.0003
$C_{N_3 0}/\text{deg.}$		-0.0142	-0.0155	-0.0161	-0.0162
$C_{M_q} + C_{M_{-1}}$		+0.4	+0.3	+0.8	+0.8
$\pm P.E.$		0.6	0.3	0.2	0.2
(CP-CG) Cal.		0.014	0.027	0.019	0.019
CG <sub>B</sub> (in.)	0.166	0.165	0.163	0.161	0.161
l (in.)	0.407	0.409	0.408	0.409	0.409
d (in.)	0.499	0.499	0.498	0.498	0.498
a (ft/sec)	920.1	915.6	911.0	928.8	936.2
Exp. a <sub>up</sub> (ft/sec)	922.5	919.1	913.5	934.8	934.8
Exp. a <sub>down</sub> (ft/sec)	921.8		914.6	933.9	933.9
Stations Used	2-27	3-27	2-26	2-27	2-27
Location of Sample Used for Reduction	midrange & Bu. Std.	midrange & Bu. Std.	midrange	midrange	Bu. Std.

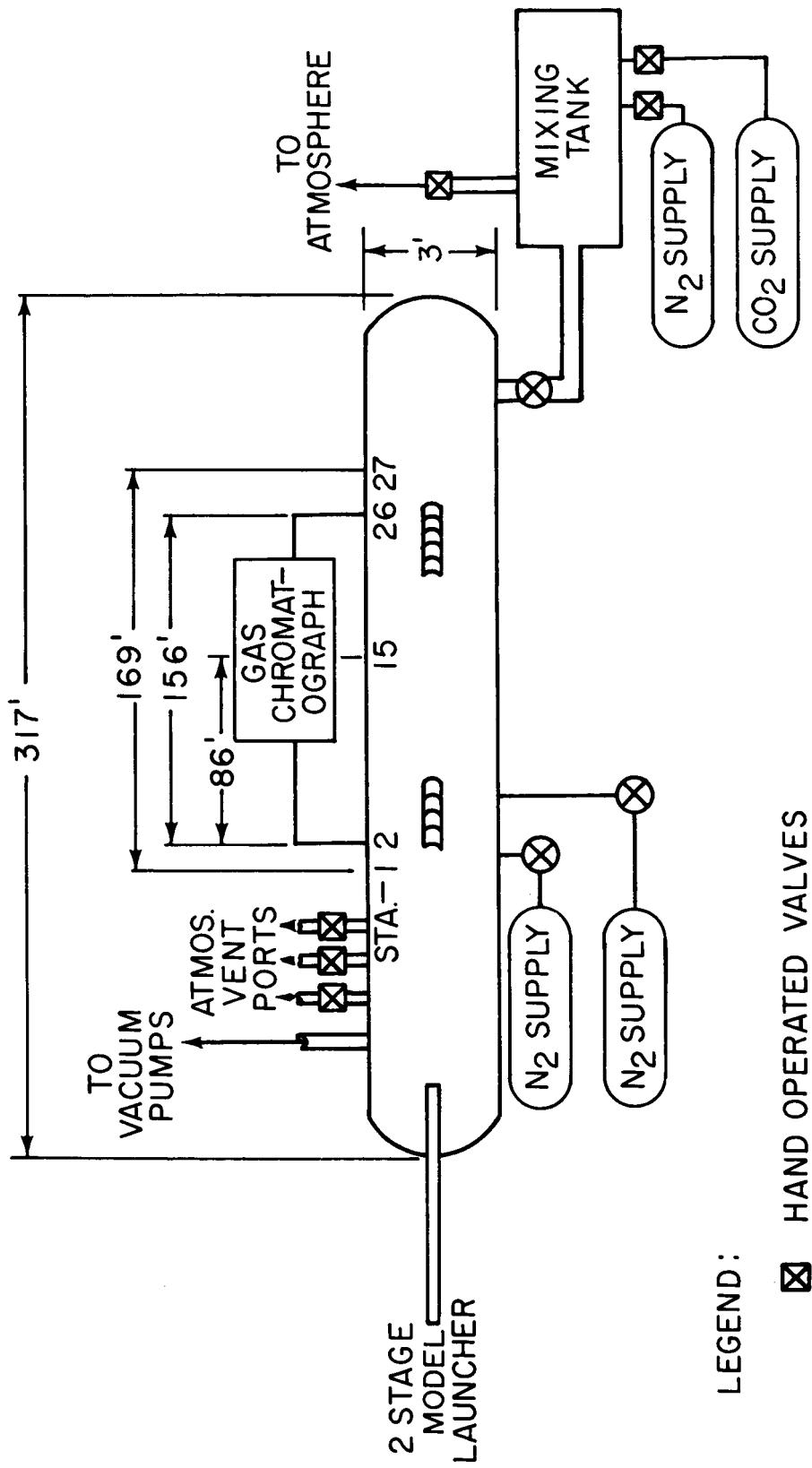
TABLE X  
DRAG AND STABILITY DATA OBTAINED FOR A-1 CONFIGURATION IN AIR

<u>Round</u>	<u>4903</u>	<u>4879</u>	<u>4882</u>	<u>4888</u>	<u>4891</u>
M	13.80	13.67	13.49	13.80	13.92
P (in. Hg)	3.51	3.37	3.49	3.54	3.48
$\frac{1}{2} C_D (\text{deg.}^2)$	41	120	127	51	46
$Re_d \times 10^{-6}$	0.460	0.439	0.448	0.465	0.462
$C_D$	0.7127	0.7211	0.7237	0.7102	0.7021
$\pm P.E.$	0.0005	0.0005	0.0005	0.0005	0.0005
$C_{D_0}$	0.7087	0.7093	0.7113	0.7052	0.6976
P.E. yaw (deg.)	0.8	1.0	1.3	0.6	0.8
P.E. swerve (in.)	0.02	0.01	0.02	0.02	0.02
$C_{M_q}/\text{deg.}$	-0.00033	-0.00054	-0.00062	-0.000429	-0.00035
$\pm P.E.$	0.00001	0.00001	0.00001	0.000008	0.00001
$C_{M_{CG}}/\text{deg.}$	-0.00060	-0.00066	-0.00073	-0.000551	-0.00047
$C_{M_{CG_0}}/\text{deg.}$	-0.00051	-0.00040	-0.00045	-0.000439	-0.00037
$C_{N_x}/\text{deg.}$	-0.0154	-0.0161	-0.0174	-0.0162	-0.0168
$\pm P.E.$	0.0003	0.0003	0.0005	0.0003	0.0005
$C_{N_{x_0}}/\text{deg.}$	-0.0151	-0.0152	-0.0165	-0.0158	-0.0165
$C_{M_q} + C_{M_1}$	+2.3	0	+0.4	-0.9	-1.7
$\pm P.E.$	0.9	0.5	0.5	0.4	0.5
(CP-CG) Cal.	0.022	0.033	0.036	0.026	0.021
CG <sub>B</sub> (in.)	0.159	0.164	0.165	0.164	0.165
l (in.)	0.409	0.410	0.410	0.410	0.410
d (in.)	0.497	0.498	0.498	0.499	0.500
a (ft/sec)	1136	1136	1136	1136	1135
Exp. a <sub>up</sub> (ft/sec)	1133	1130	1129	1132	1131
Exp. a <sub>down</sub> (ft/sec)	1134	1131	1131	1132	1131
Stations Used	3-27	5-27	3-27	3-27	3-27
Location of Sample Used for Reduction	air	air	air	air	air



ALL DIMENSIONS  
IN CALIBERS.

FIGURE I NASA-JPL CONFIGURATIONS



- LEGEND:
- HAND OPERATED VALVES
  - ELECTRICALLY OPERATED VALVES
  - EXPERIMENTAL SPEED OF SOUND MEASURING INSTRUMENTATION

FIG. 2 INSTRUMENTATION LOCATION IN THE PRESSURIZED BALLISTICS RANGE No.3

K<sub>1</sub> 10 X 10 TO THE CM. 359.14  
KEUFFEL & ESSER CO. U.S.A.

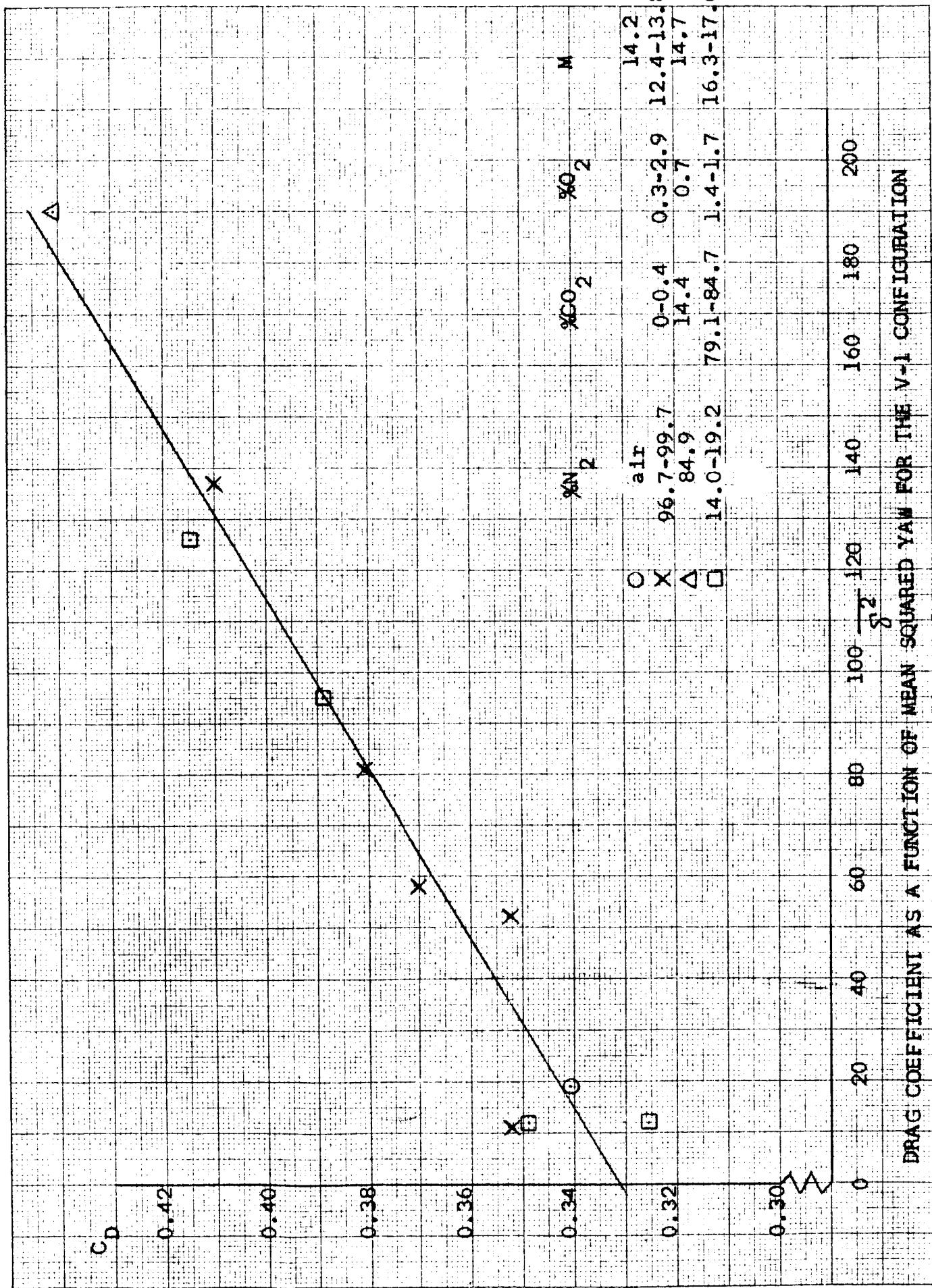
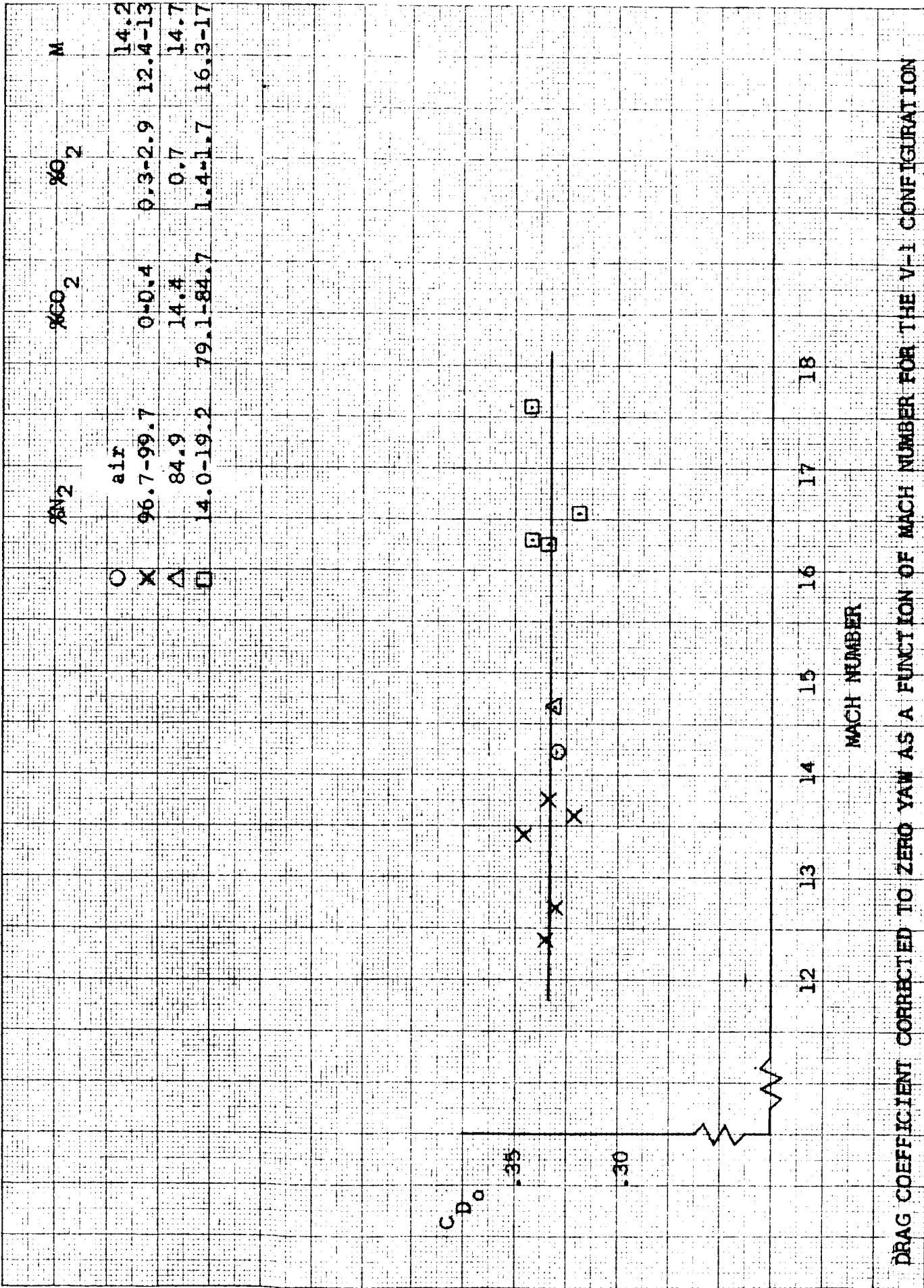
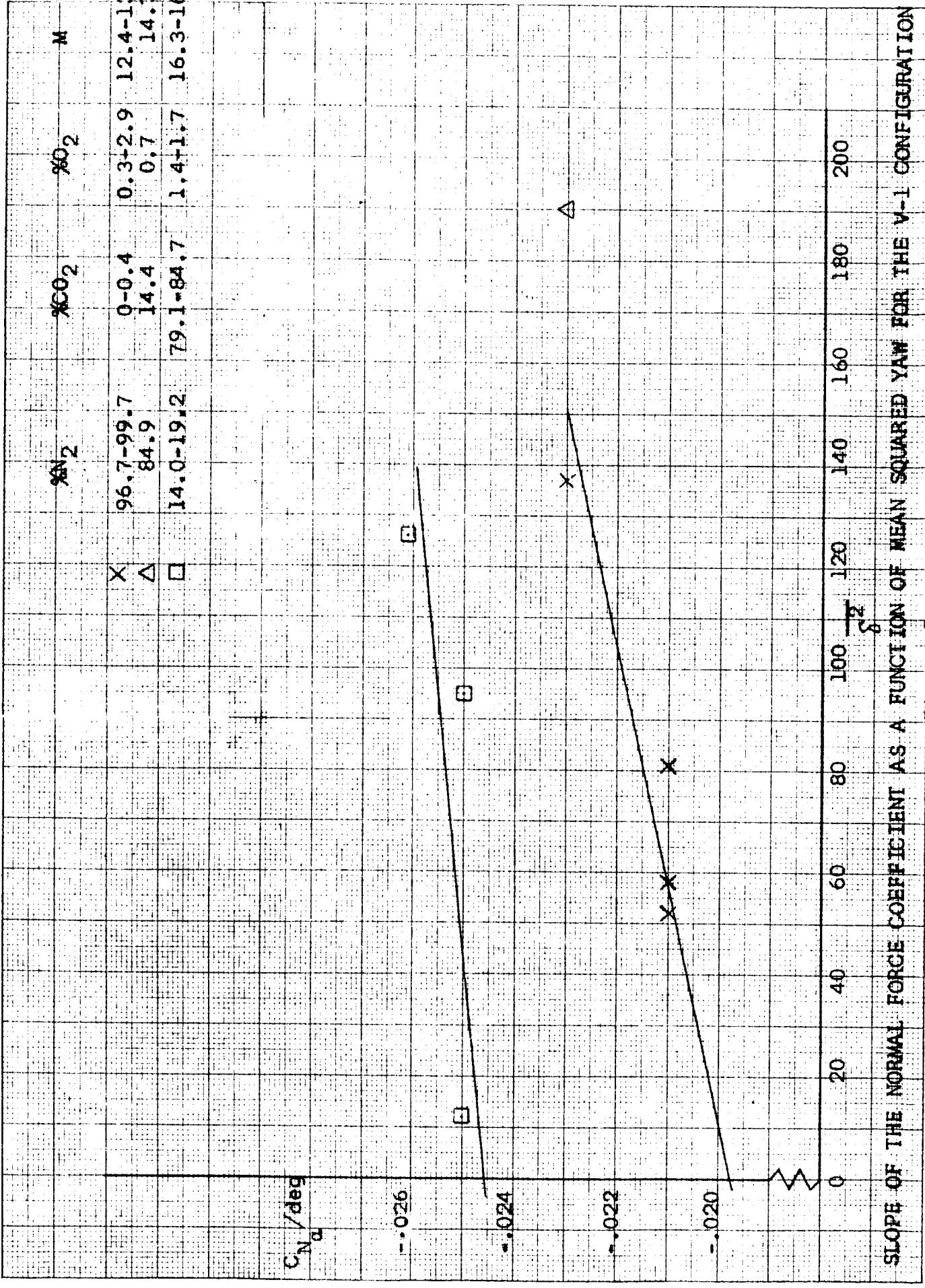


Figure 3





SLOPE OF THE NORMAL FORCE COEFFICIENT AS A FUNCTION OF MEAN SQUARED YAW FOR THE V-1 CONFIGURATION

Figure 5

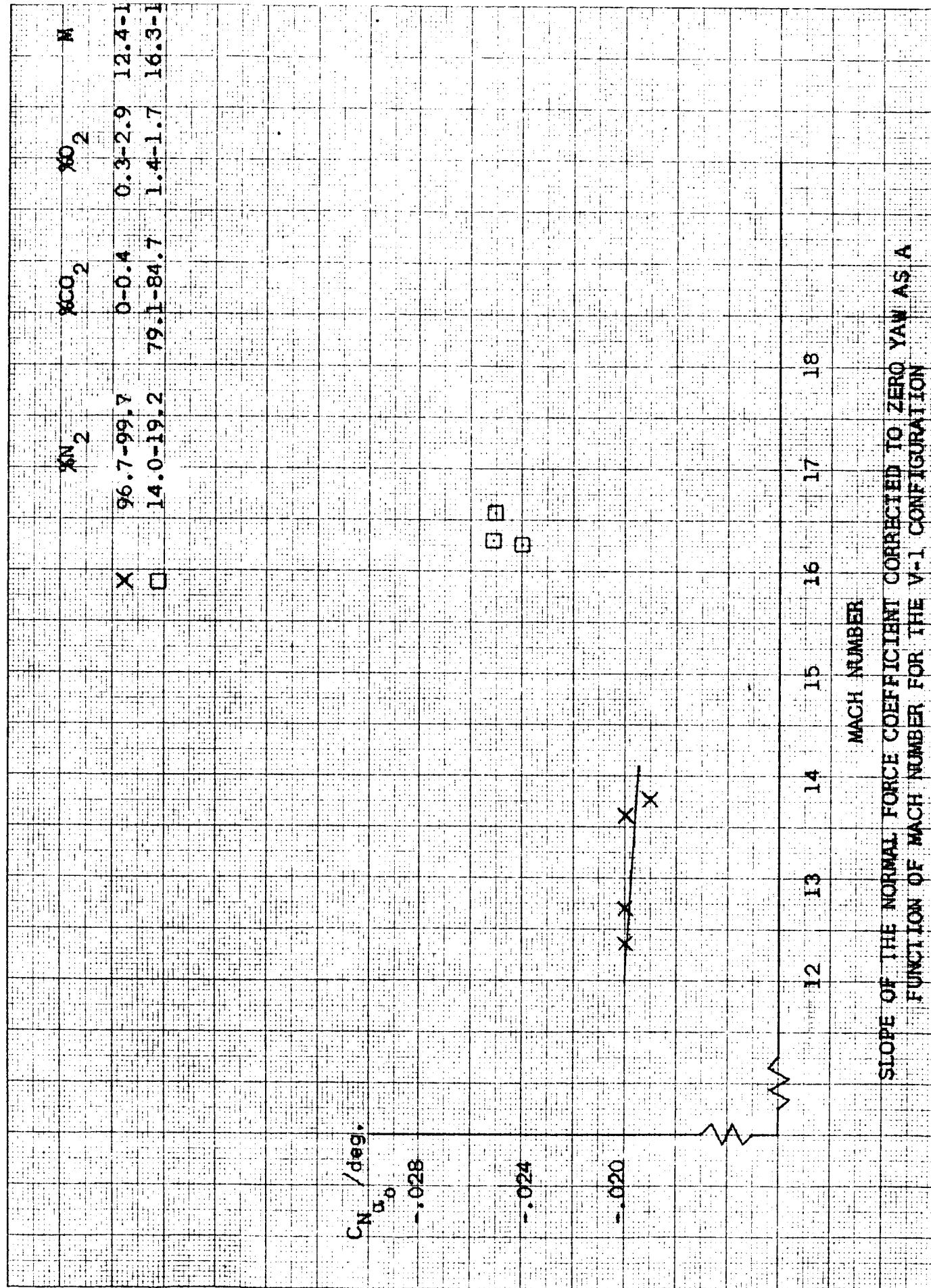
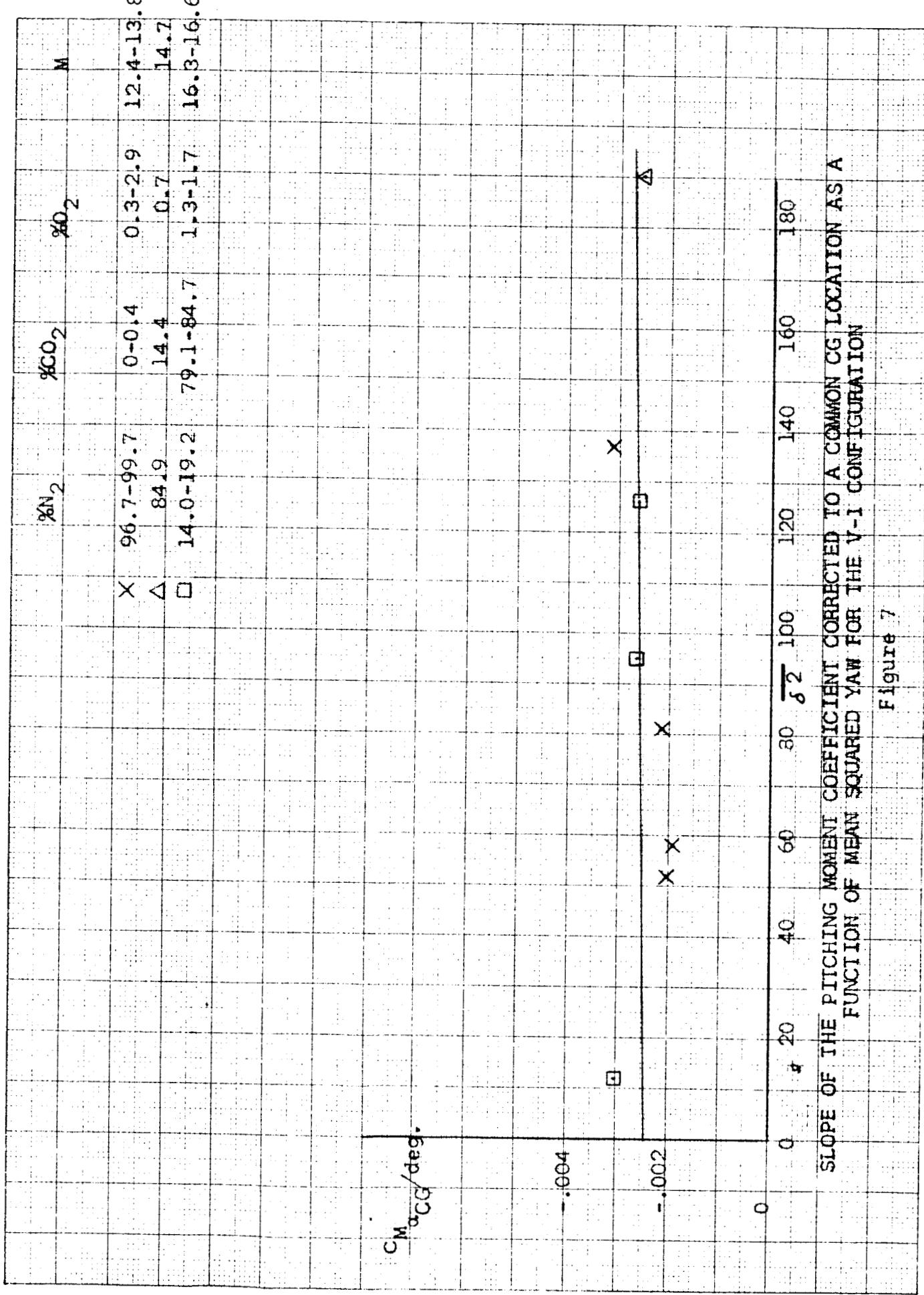


Figure 6

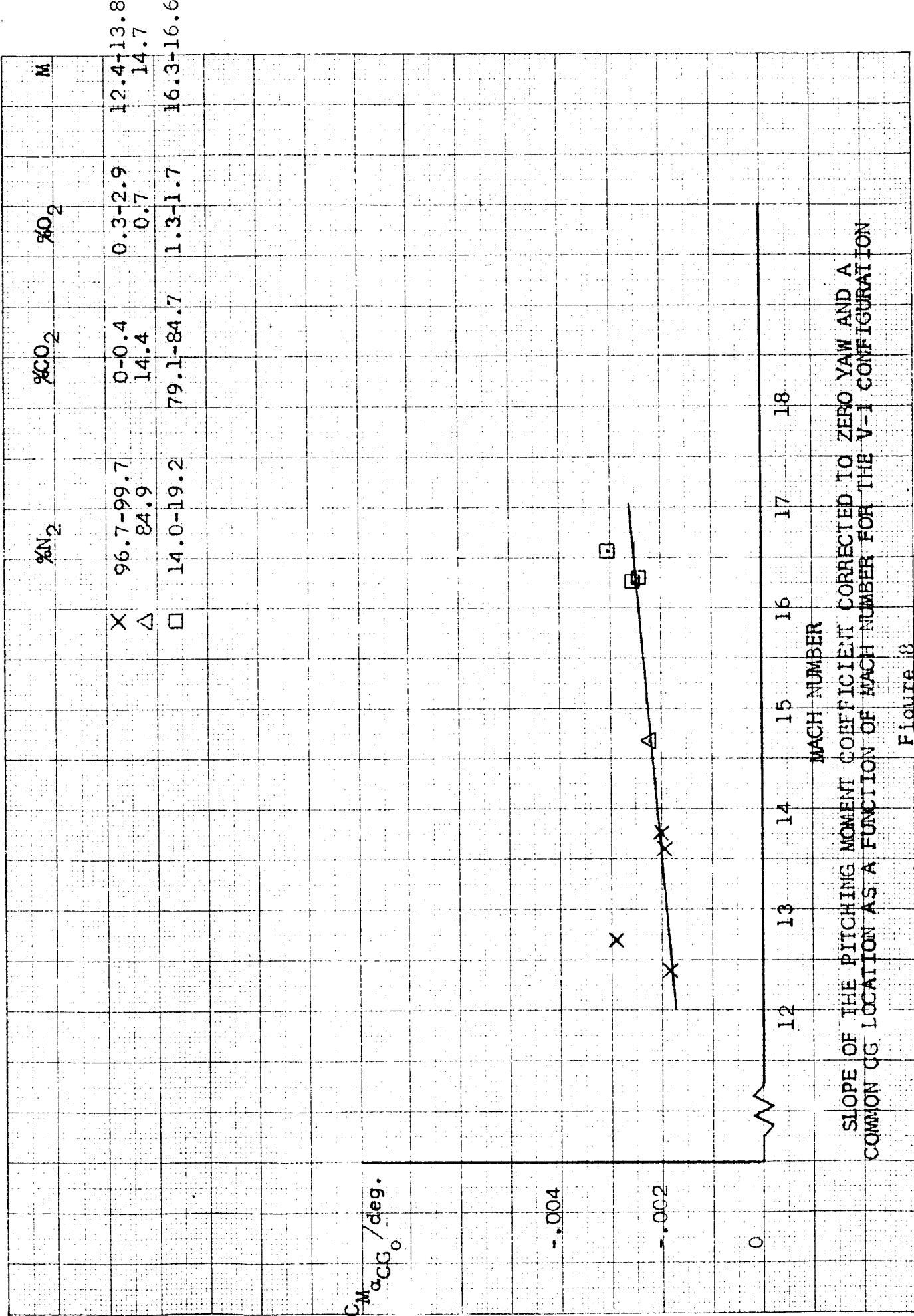
SLOPE OF THE NORMAL FORCE COEFFICIENT CORRECTED TO ZERO YAW AS A FUNCTION OF MACH NUMBER FOR THE V-1 CONFIGURATION

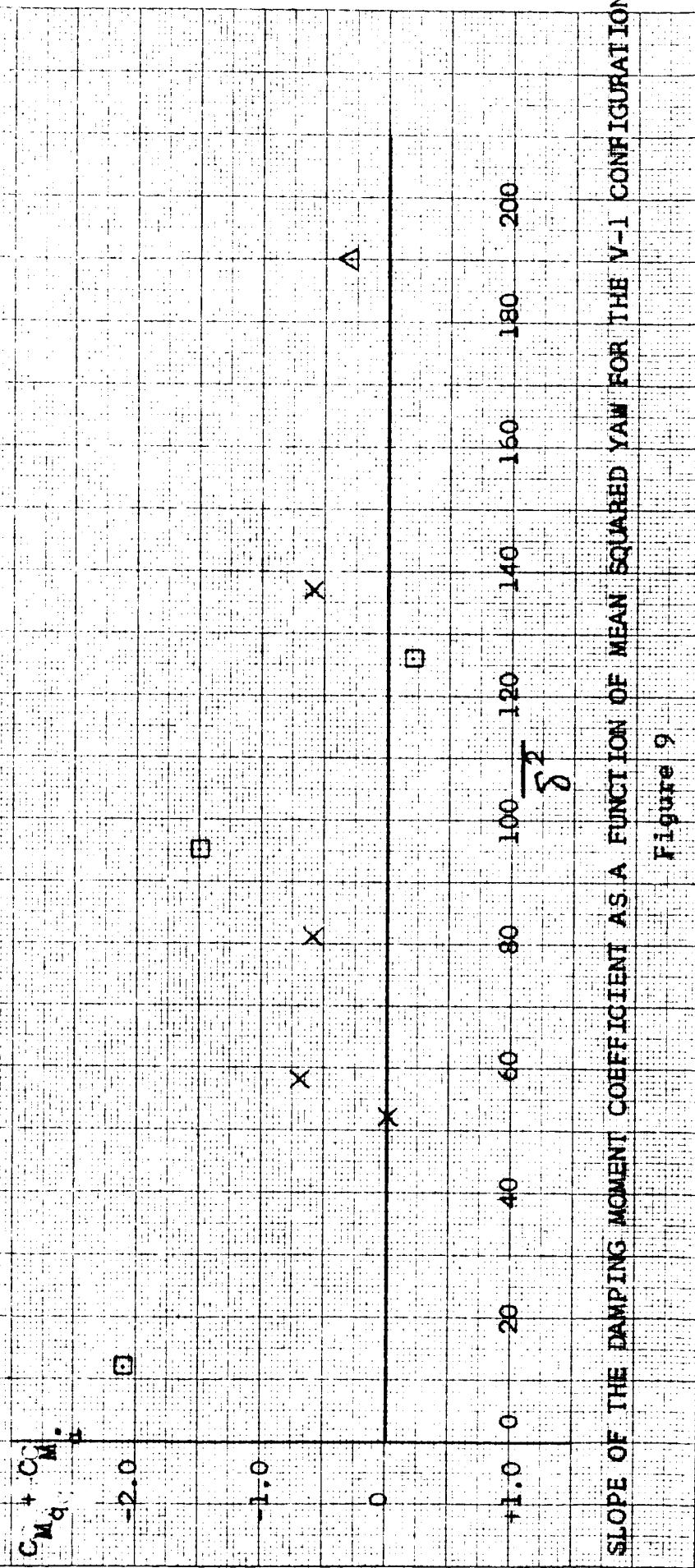
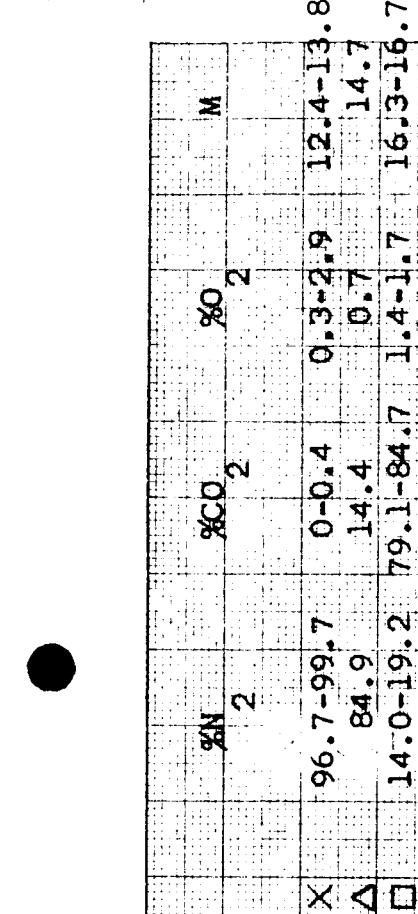


SLOPE OF THE PITCHING MOMENT COEFFICIENT CORRECTED TO A COMMON CG LOCATION AS A FUNCTION OF MEAN SQUARED YAW FOR THE V-1 CONFIGURATION

Figure 7

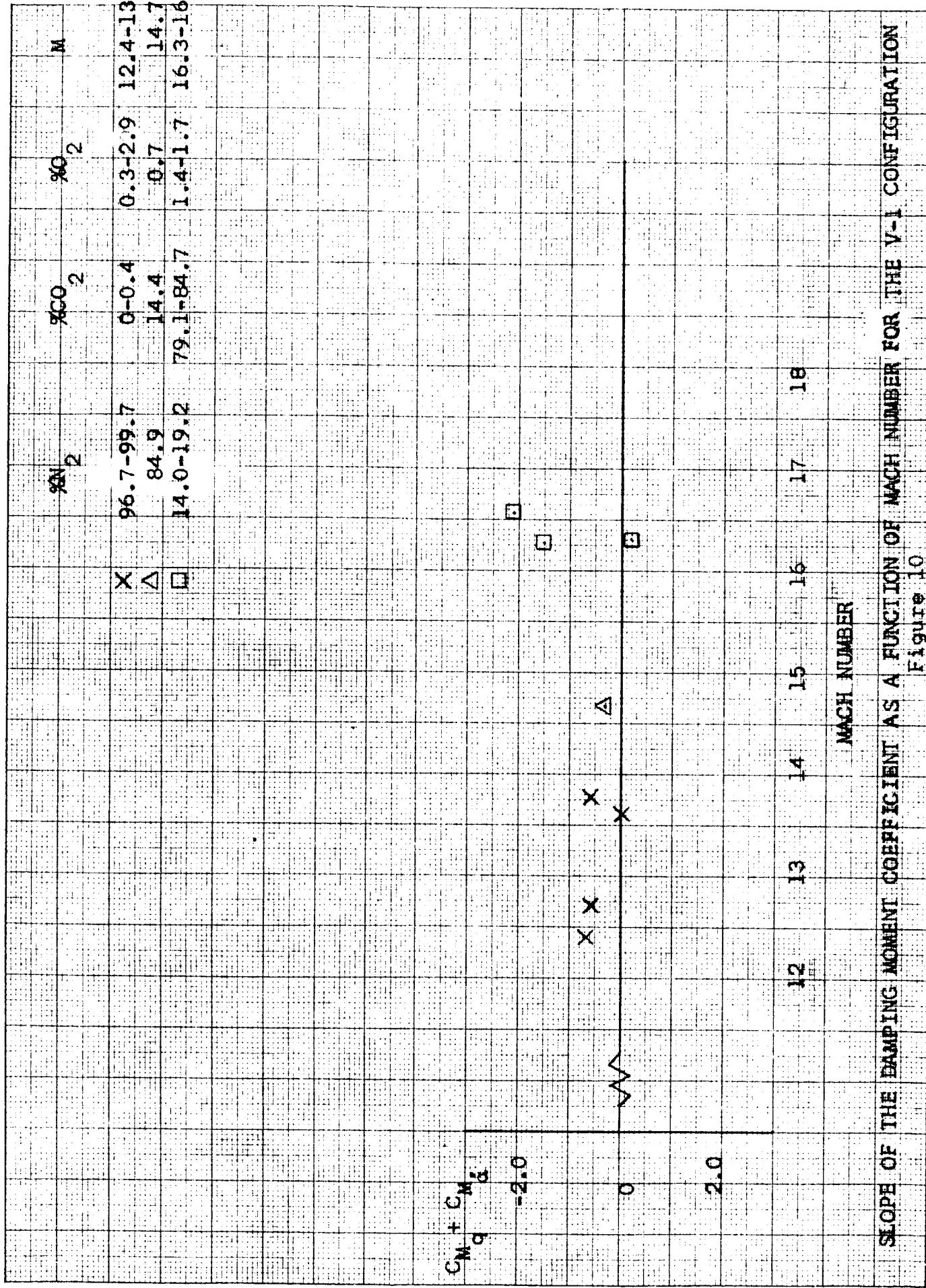
10 X 10 TO THE CM.  
KEUFFEL & FISHER CO.





SLOPE OF THE DAMPING MOMENT COEFFICIENT AS A FUNCTION OF MEAN SQUARED YAM FOR THE V-1 CONFIGURATION

Figure 9



DRAG COEFFICIENT AS A FUNCTION OF  
MEAN SQUARED YAW FOR THE A-1 CONFIGURATION

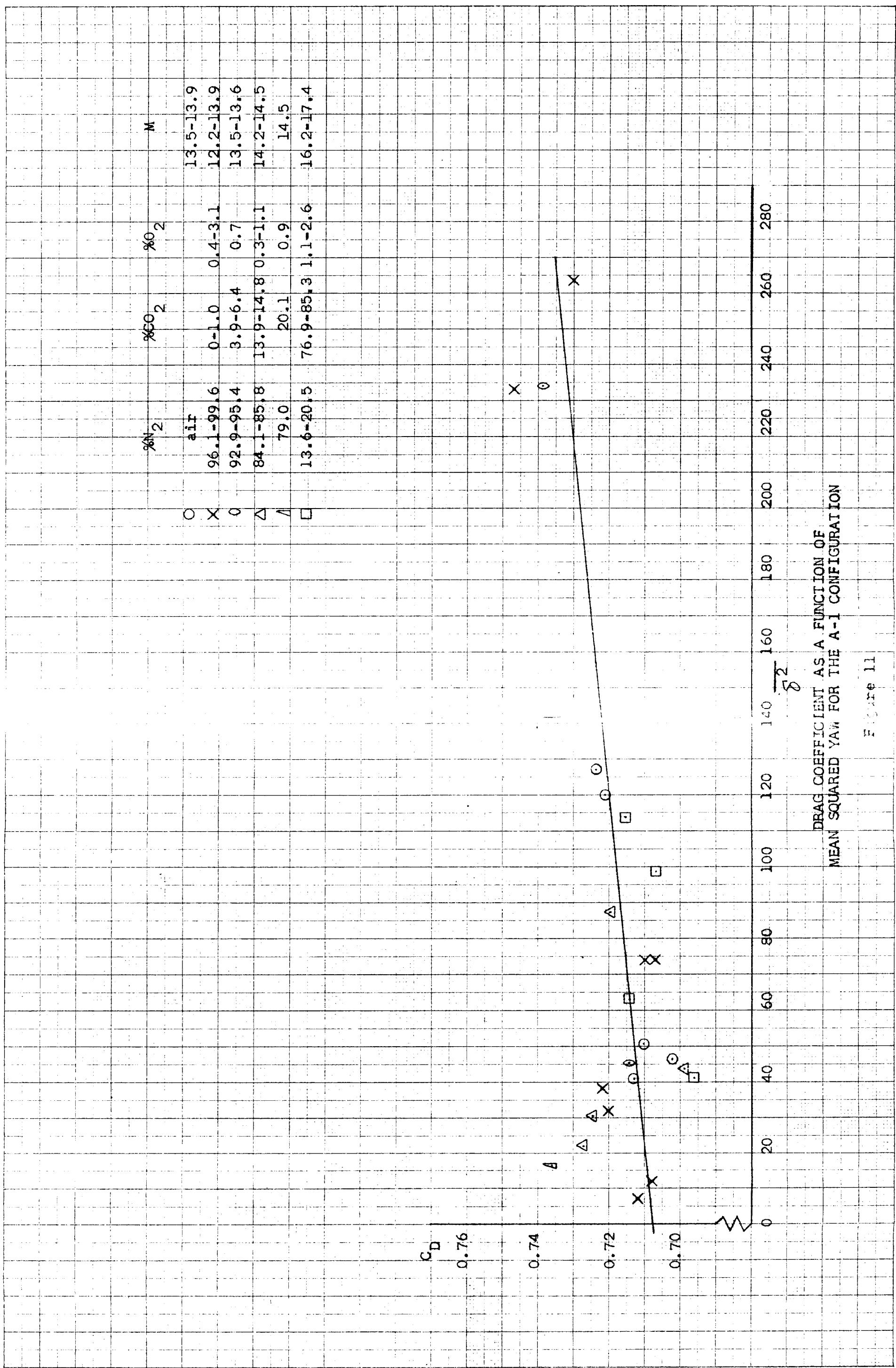
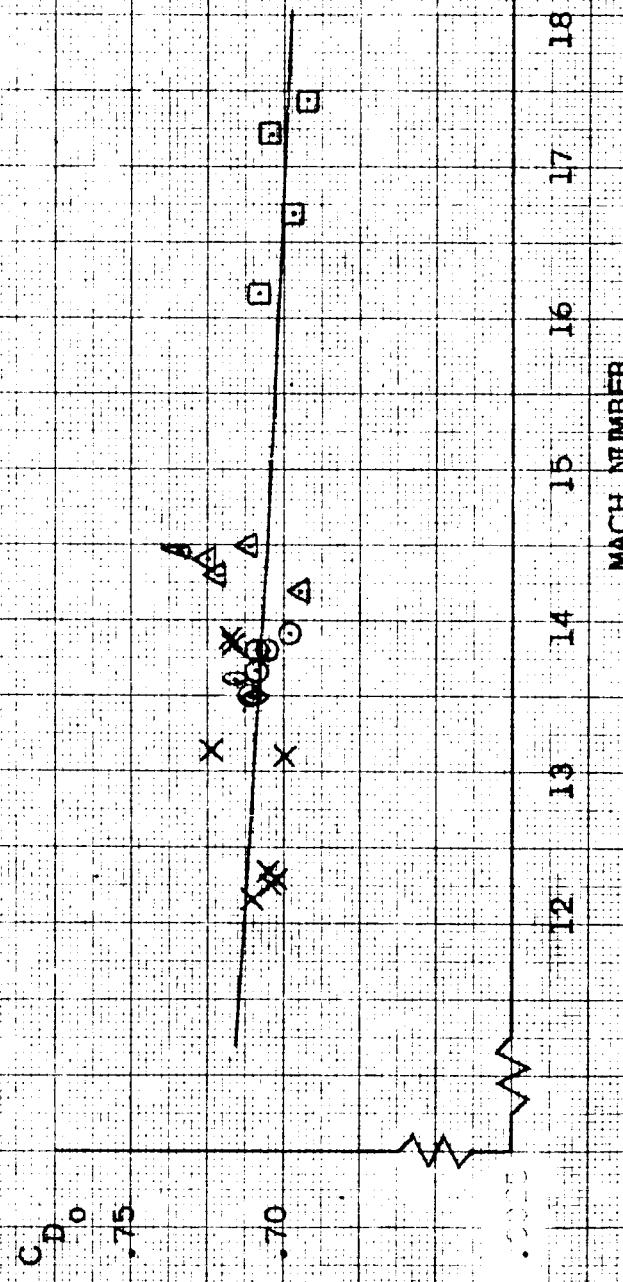


Figure 11

	%N <sub>2</sub>	%CO <sub>2</sub>	%O <sub>2</sub>	M.
O	96.1-99.6	0-1.0	0.4-3.1	13.5-13.
X	92.9-95.4	3.9-6.4	0.7	13.5-13.
0	94.1-85.8	13.9-14.8	0.3-1.1	14.2-14.
△				
▽	79.0	20.1	0.9	14.5
□	13.6-20.5	76.9-85.3	1.1-2.6	16.2-17.



## DRAG COEFFICIENT CORRECTED TO ZERO YAW AS A FUNCTION OF MACH NUMBER FOR THE A-1 CONFIGURATION

	%N <sub>2</sub>	%CO <sub>2</sub>	%O <sub>2</sub>	M
O	air			13.5-13.9
X	96.6-97.5	0.9-1.0	1.5-2.5	12.3-13.1
O	92.9-95.4	3.9-6.4	0.7	13.5-13.6
△	84.1-85.1	14.4-14.8	0.5-1.1	14.3-14.5
□	79.0	20.1	0.9	14.5
	13.6-20.5	76.9-85.3	1.1-2.6	16.7-17.4

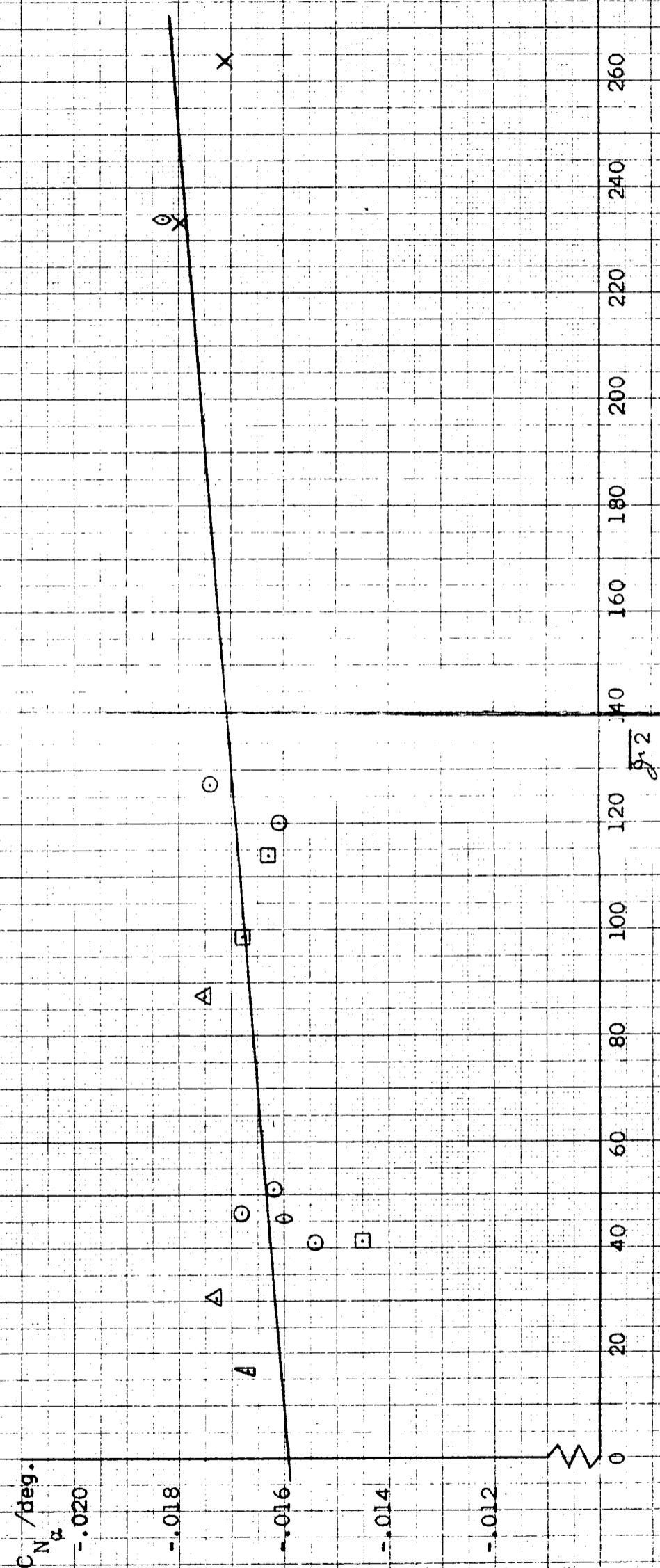
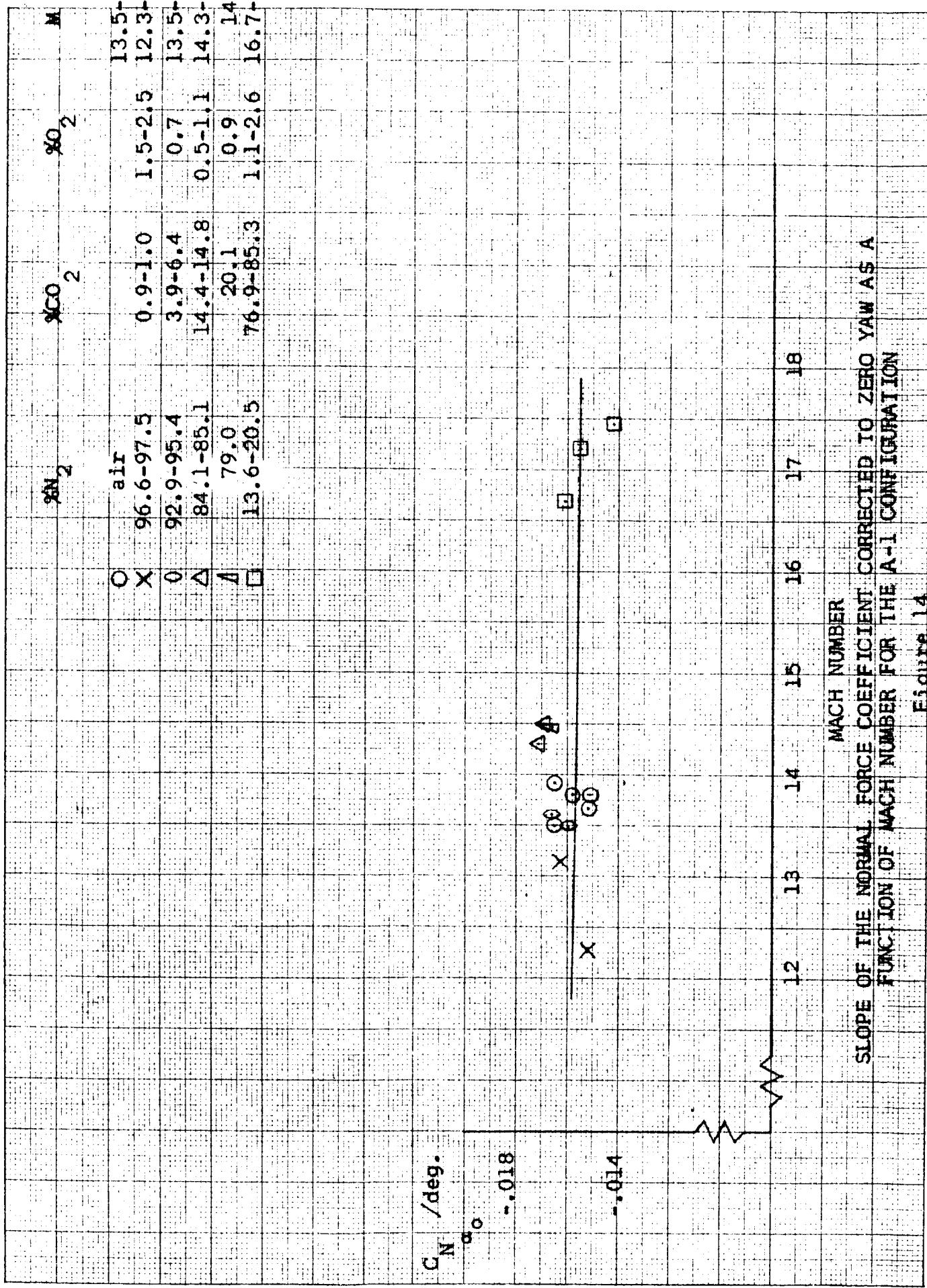
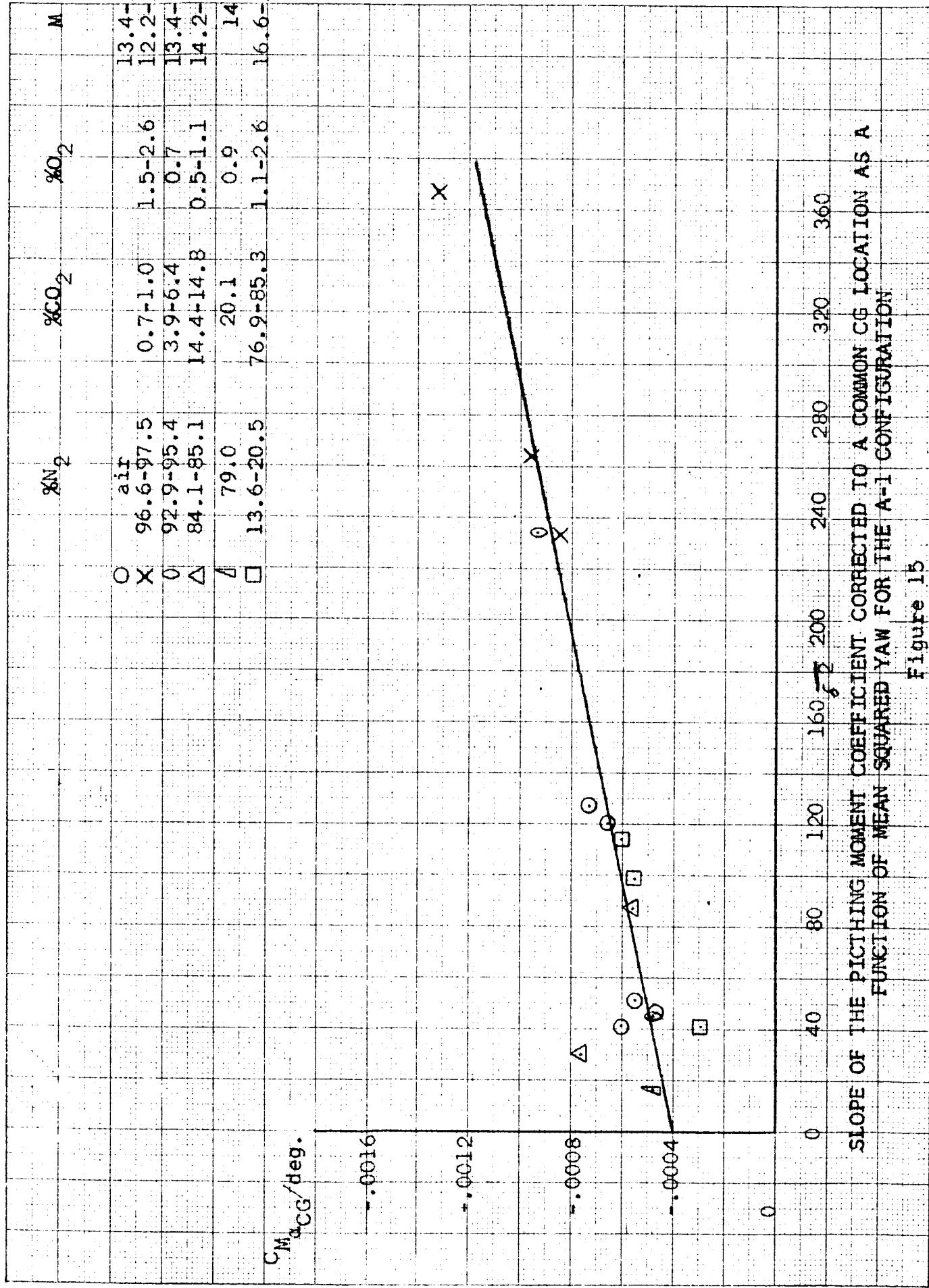


Figure 13





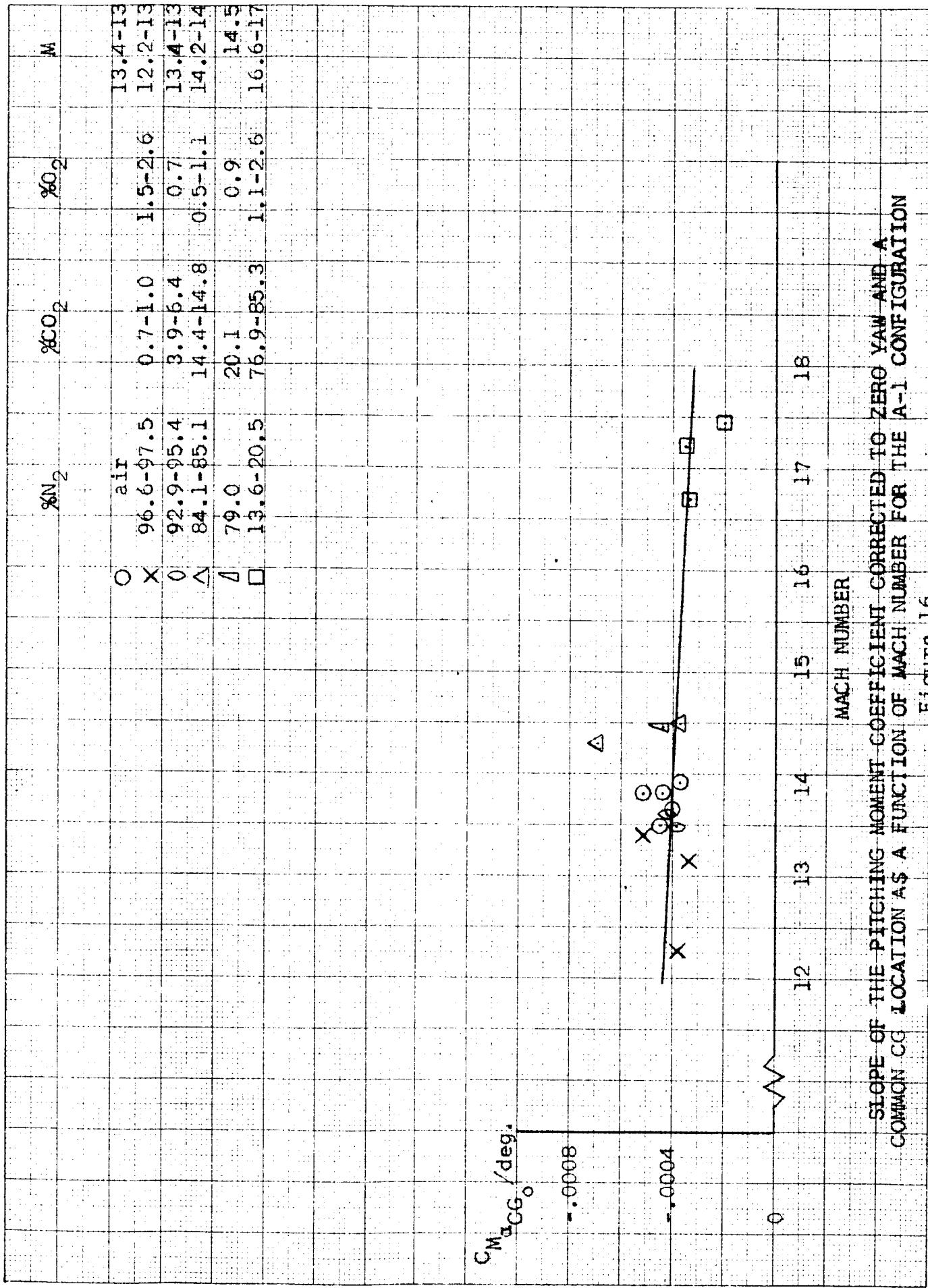
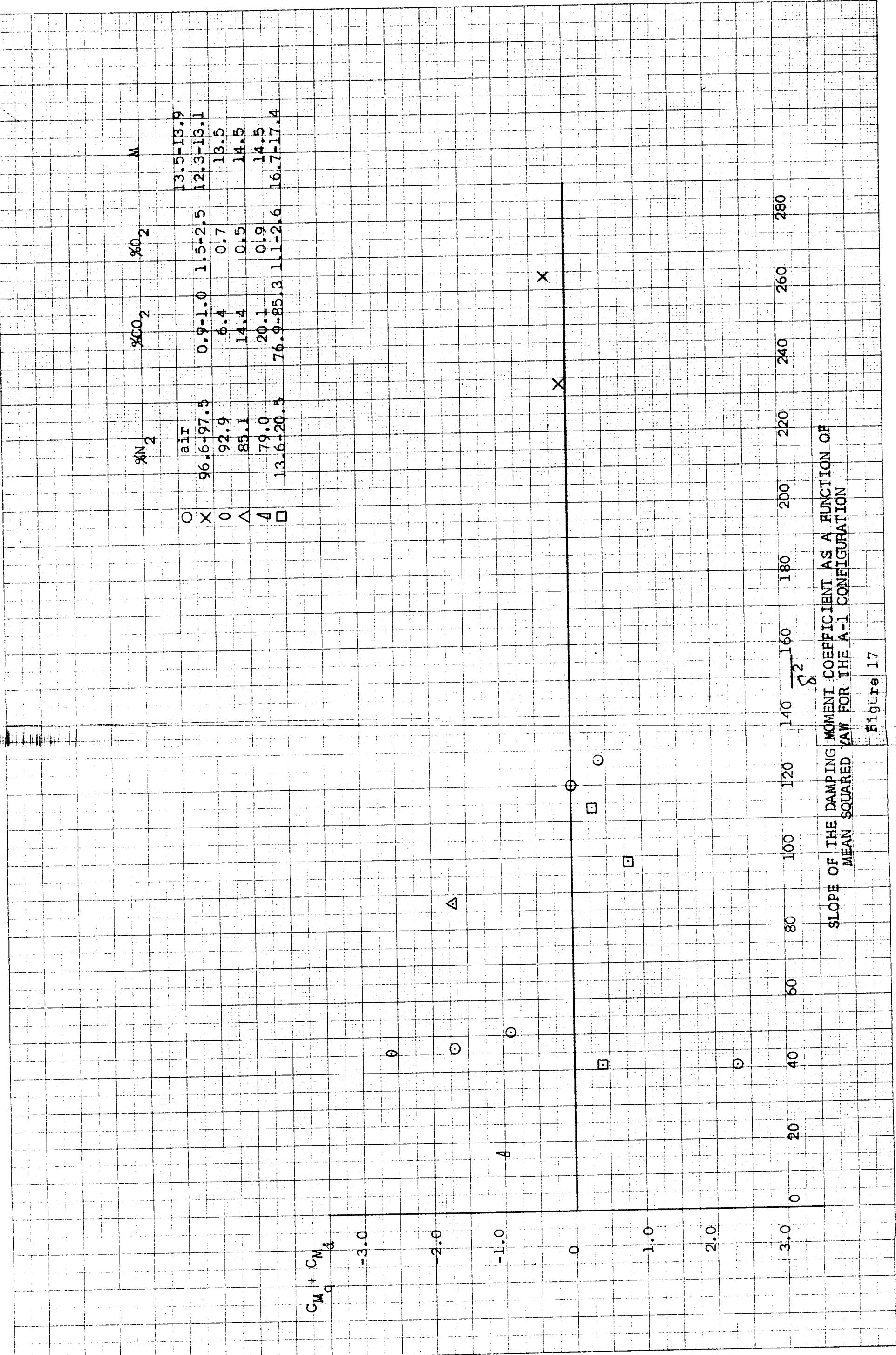
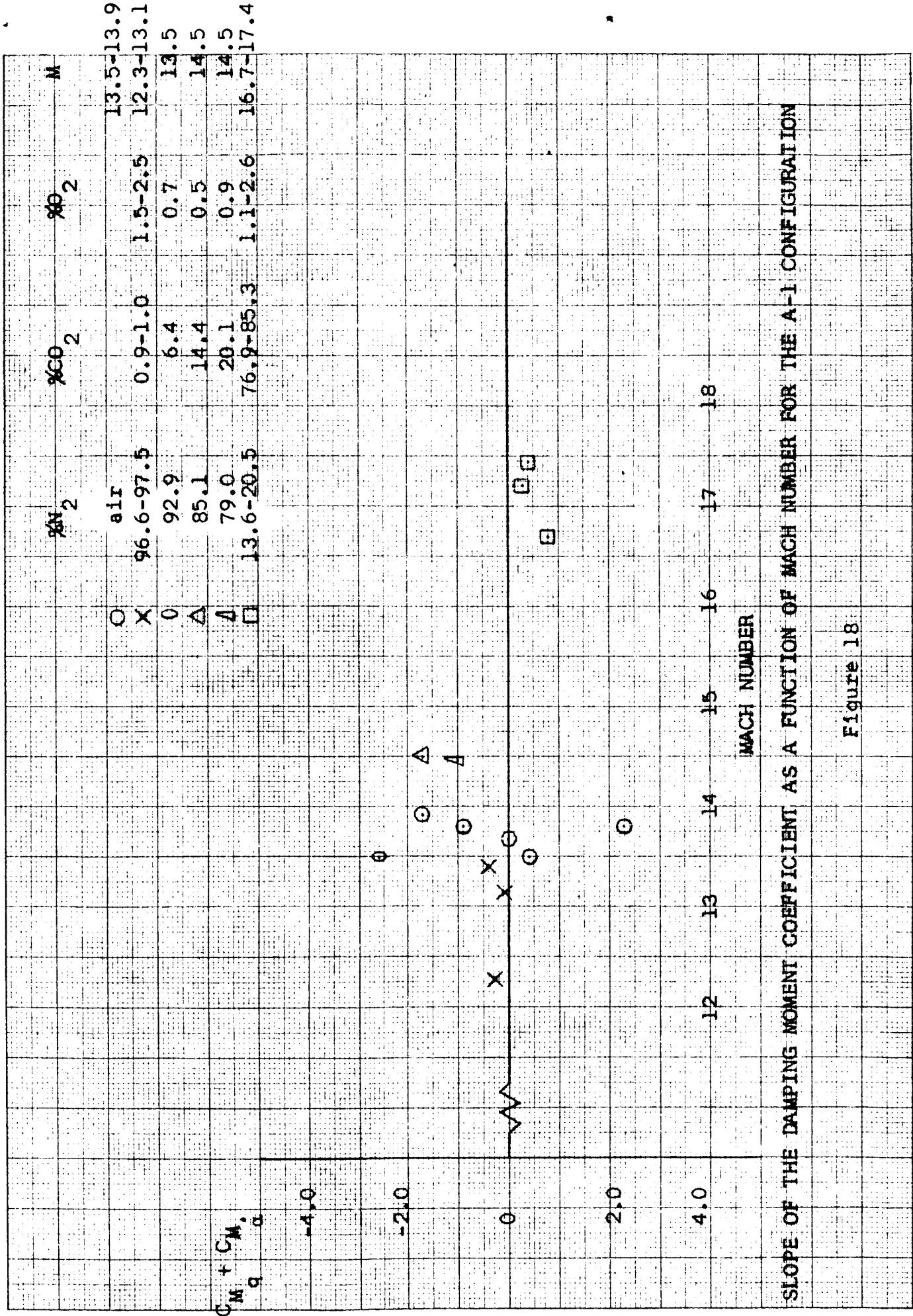


Figure 16



SLOPE OF THE DAMPING MOMENT COEFFICIENT AS A FUNCTION OF MEAN SQUARED YAW FOR THE A-1 CONFIGURATION

Figure 17



SLOPE OF THE DAMPING MOMENT COEFFICIENT AS A FUNCTION OF MACH NUMBER FOR THE A-1 CONFIGURATION

Figure 18